I/KCl ratio is varied to give the graduated priming effect. The detonators consist of a base charge of 2 pressings each of 0.55 g. of a mixt. of I with 0–88% KCl, pressed to a d. of 1.60, on top of this 0.1 g. pure I, and then 0.55 g. $Hg(CN)_2$ as primer. PbN_6 may also be used as primer. The dimensions of the detonator case, the loading pressure, and other factors are kept to close tolerances to ensure consistent results. These detonators give greater accuracy than previously known types. For testing com. explosives, it is sufficient to use suitable single grades of detonators. A suggested suitable range is as follows: I/KCl ratios 100/0, 80/20, 70/30, 60/40, 50/50, 40/60, 30/70, 20/80, 16/84, and 12/88. For precision work, such as research into factors affecting detonation properties, the reference detonators must be very accurately made. This may involve weighing all the charges on a precision balance and the use of a special pressing mold with accurately dimensioned stopping pieces to make small amts. of detonators. J. Schofield

Comparison of different blasting caps regarding their initiating efficiency to aid in choice of a uniform test fuse. Ernst Haeuseler (Inst. Chem. Tech. Untersuch., Bonn, Ger.). *Explosivstoffe* 11(11), 226–36(1963)(Ger). Fifteen blasting caps and fuses [contg. $Hg(NCO)_2$ (I) or a I-$KClO_3$ mixt., some no. 8 blasting caps and fuses, a no. 9 blasting cap, and Nitropenta or Hexogen test fuses] were tested for their initiating efficiency on a Pb plate of 8 mm. thick, against TNT-talc press cakes (contg. 5–60% talc) placed on a Kast app., and in a Trauzl Pb block in comparison with a 70/30 TNT-talc mixt., NH_4ClO_4 (II), and picric acid (III). The values of both tests against a TNT-talc mixt. are comparable, but testing on a lead plate gave different values; the effect of the casing material (Cu, Al) was observed. Tests of the blasting caps, contg. I against the TNT-talc mixt. gave much lower values than other no. 8 blasting caps, but the Pb plate test gave comparable results. The efficiency of the Nitropenta or Hexogen fuses (they were most effective of all blasting caps tested) increased with the weight and d. of the charge. The max. values of the Pb-block test against II, were found for no. 8 blasting caps with Al casings; high values were also found for all powerful fuses. The testing against very-sensitive III gave a much lower difference in values. The contribution of the blasting cap to the Pb-block value of a blasting agent was detd. by a Pb-block test of a no. 8 blasting cap alone in an inert medium (NaCl or H_2O). A new test fuse is proposed; it contains 0.3 g. $Pb(N_3)_2$ (compacting pressure 380 kg./cm.^{2}), Nitropenta 0.2 g. (pressed), and Nitropenta 0.4 g. (compacting pressure 380 kg./cm.^{2}) in a Cu casing and has a O balance of −0.07 g. Jirina Seitlova

Introduction of AN-FO [ammonium nitrate-fuel oil] explosive at the Gonzen iron ore mine, Sargans. R. Amberg. *Z. Erzbergbau Metallhuettenw.* 19(4), 169–72(1966)(Ger). The explosive was tested by measuring the detonation velocity and comparing with conventional explosives under similar conditions. The AN-FO explosive, used in cartridge form, improved output and reduced costs. H. Stoertz

AN-FO [ammonium nitrate-fuel oil] in German ore mining. Helmut Eckhardt. *Z. Erzbergbau Metallhuettenw.* 19(4), 163–6 (1966)(Ger). Nitroglycerin-free explosives consisting of NH_4NO_3 and C compds. are described. Details of their application in mining are given, with special attention to 3 mines in West Germany (Maubacher Bleiberg, Buelten Adenstedt, Wahlverwahrt-Nammen). The explosives are not water resistant and therefore cannot be used in H_2O-filled drill holes. The spacing of bore holes, the compn. of fumes, and the purling capacity of the explosives are discussed. Loading techniques are described. H. Stoertz

Explosive safety container. Martin F. Zimmer and Leo K. Asaoka (U.S. Naval Propellant Plant, Indian Head, Md.). *Explosivstoffe* 11(11), 237–42(1963)(Eng). Medium-d. polyethylene cylinders with explosive stored in a central cylindrical cavity are suitable, for low-order explosions, as safety containers. Other materials, Al alloy, polyurethan, nylon, Lucite, cross-linked polystyrene, poly(vinyl chloride), Teflon, and polypropylene were unsatisfactory or minimally acceptable. Polyurethan cylinders, even when reinforced with an external sleeve of Al, stainless steel, or 3 layers of Dacron fishing line, were not as sturdy as polyethylene. The low-order explosion of $\leq$500 g. nitroglycerin is confined, without fragmentation, by a polyethylene cylinder of 31.2 cm. diam., 28 cm. long (estd.) in a cavity 5.08 cm. diam., 16.5 cm. deep; a 15-g. charge is similarly confined by a cylinder of 10 cm. diam., 12 cm. long (estd.) in a cavity of 1.35 cm. diam. and 7.0 cm. deep. Jay A. Young

[illegible] air and in water. M. Giltaire and J. Cocu. *Explosifs* 18(3), 77–86(1965)(Fr). Results of a study are presented which show the relation between the frequency of detonation initiation in a primed charge and the transmission distance from the detonating fuse to the explosive. Four coated, powd. explosive compds. were investigated, two of which were dynamites designated GC 16 and GDC 1, resp., and 2 nitrates, N 66 and N 7A. The transmission distance in each case was defined as that distance which produced a frequency of misfiring of approx. 50%. These distances [illegible] cm. for GC 16, N 66, GDC 1, and [illegible] were 6.4–7.1, 8–9, 10.2–10.8, and 5.9–6.8 mm [illegible] 66, N 7A, and GDC 1, resp. Also discussed a[illegible] charge length and diam. and α, the angle made by [illegible] and the horizontal axis of the charge on the det[illegible] Although the transmission distances from fuse to [illegible] the same order of magnitude in both air and wa[illegible] plosive, the distance for N 7A is much less tha[illegible] compds. It is recommended that the fuse be pl[illegible] with the charge in actual practice. The result[illegible] testing are not valid for a pressurized system. [illegible] evidence that, when pressure is placed on the w[illegible] is initiated and subsequently arrested by a c[illegible] nomenon. An analogous situation is encount[illegible] when one charge, placed too close to a second, [illegible] second by exploding before it.

Handling and testing unstable materials. E[illegible] J. A. Ford (Thiokol Chem. Corp., Brigham City, [illegible] *Eng. Prog.* 62(3), 98–104(1966)(Eng). Safety in [illegible] handling of hydrazinium diperchlorate was teste[illegible] friction, electrostatic, heat stability, and detona[illegible] Interstate Commerce Commission classificatio[illegible] using detonation shock tests, fire sensitivity, im[illegible] ity tests. Long-term storage, water deluge, a[illegible] tests were also made. The tests described a[illegible] most materials with high energy contents. G. [illegible]

Explosion hazards of ammonium nitrate unde[illegible] R. W. Van Dolah, C. M. Mason, F. J. P. Pe[illegible] and D. R. Forshey (U.S. Bur. of Mines, P[illegible] *U.S., Bur. Mines, Rept. Invest.* No. 6773, 79 [illegible] The conditions under which NH_4NO_3 (I) may ex[illegible] jected to intense fire exposure have never been d[illegible] trinsic sensitivity of I and I systems was stud[illegible] techniques. Fertilizer-grade I was detonated, [illegible] temps. very large charges and strong explosive [illegible] used to achieve detonation. The crit. diam. of [illegible] at elevated temps., implying an increase in se[illegible] coated with 3% clay were less sensitive than [illegible] parting agent. H_2O in small amts. increased the [illegible] of I-fuel oil mixts. (II). In simulated free-f[illegible] transitions to detonation in I systems were not[illegible] up to 10,000 psig. An inverted vented vesse[illegible] used to overcome the exptl. limitations of the [illegible] and to develop more rigorous burning conditi[illegible] to detonation were obtained with I intimately [illegible] oil, polyethylene, or paper. Hot I was det[illegible] velocity bullet impact, and II were sensitive to i[illegible] ments from another II charge several diams. aw[illegible]

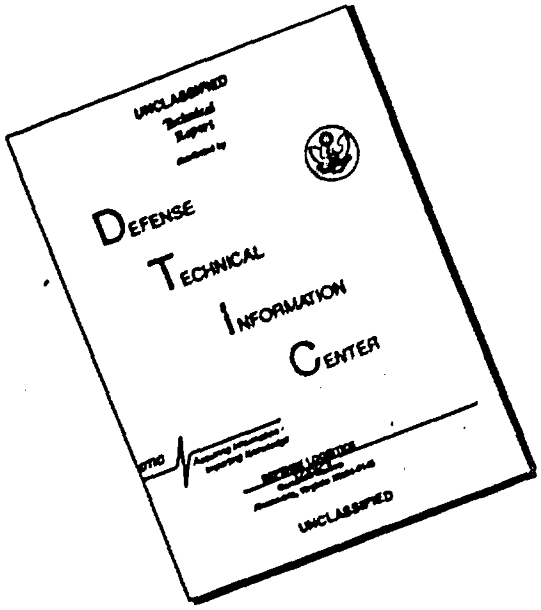
Stabilizing acetylene with cyclopentadiene. S. M. Kogarko, I. I. Strizhevskii, A. F. Plate, [illegible] nishnikova. *Neftekhimiya* 6(1), 101–4(1966)[illegible] 62, 7578e. C_2H_2 mixts. proposed for utilizatio[illegible] of bicyclo[2.2.1]hepta-2,5-diene (I) by conde[illegible] with cyclopentadiene (II) were examd. for their [illegible] considering the optimum conditions for the syn[illegible] 340° and 6–13 atm. with the reaction temp. de[illegible] creasing pressure and the yields of I being prac[illegible] ent of the changes in the C_2H_2:II ratio from 2:1 [illegible] placement of N by other diluents. The expts. [illegible] in a spherical 120-mm. reactor by burning a [illegible] center by a condenser discharge. The amts. o[illegible] or isopentane (III) in the mixts. were 40–5, 20 [illegible] resp. Data for the explosive limits in mixts. [illegible] III, C_4H_{10}, or II are tabulated for 300° and [illegible] and 4.2–10.3 atm., 300° and 3.6–15.2 atm., a[illegible] 2.0–7.5 atm., resp. The stabilizing action of [illegible] creased in the series N, II, C_4H_{10}, and III. [illegible] structures, II had a lower stabilizing effect th[illegible] double bond. Since II is used in the synthesis, [illegible] tion mixt. with N is said to be useless. The exp[illegible] binary C_2H_2 1:1 mixt. at 300° was 6.7 atm. [illegible] C_2H_2 must be decreased at higher pressures [illegible] rate of pressure increase and the max. pressu[illegible] both decreased on dilg. C_2H_2 with the stabiliz[illegible]

Fluorine fluorosulfate (SO_3F_2) may be explo[illegible] Cady (Univ. of Washington, Seattle). *Chem.* [illegible] 40(1966)(Eng). In the prepn. of peroxydisul[illegible] sulfuryl fluoride (SO_2F_2), and perhaps other com[illegible] These by-products were distd. into a cold, c[illegible] strong enough to store gas at 135 atm. (The [illegible] SO_3F_2 is ~10 atm.). On warming to room te[illegible] exploded, suggesting that a chem. explosion [illegible] than a simple expansion. SO_3F_2 decomp. >2[illegible] explosion is known.

Liquid hydrogen tank insulation for the S-II [illegible] Hammond, Jr. (N. American Aviation, Inc., [illegible] *Chem. Eng. Progr., Symp. Ser.* 62(61), 2[illegible] The insulation for the S-II booster is construc[illegible]

Enclosure (1)

DISCLAIMER NOTICE



THIS DOCUMENT IS BEST QUALITY AVAILABLE. THE COPY FURNISHED TO DTIC CONTAINED A SIGNIFICANT NUMBER OF PAGES WHICH DO NOT REPRODUCE LEGIBLY.

EXPLOSIVE SAFETY CONTAINER

by

Dr. Martin F. Zimmer and Leo K. Ascoka

Research and Development Department U. S. Naval Propellant Plant Indian Head, Maryland USA

FFK 166 (7) 710 (6)

Acknowledgment

This research was supported by the Bureau of Weapons, Department of the Navy. The authors wish to thank Dr B. Bartocha, Dr. G. Tesi and Dr. J. G. Tuono for their support and encouragement during the course of this investigation. We also wish to thank Roy G Calvert for his faithful help in performing the experimental work and S. Wagner for cooperation in obtaining necessary data for the physical property measurements.

1. Abstract

Polyethylene containers that safely hold comparatively large loads of explosive materials have been developed and investigated. At first developmental studies were made with polyurethane containers. The effects of material properties, shape and size of both inner tubes and containers, and the shock attenuation of the container material were investigated. Various materials were evaluated as possible candidates for fabricating the containers, and polyethylene was found to be most suitable. Two different sizes of containers were developed. A 10-cm-diameter container can easily withstand the explosion of 15-g of nitroglycerin, and a 32-cm-diameter container, 500-g. The smaller container weighs 0.775 kilogram and is easily handled in one hand; the larger container weighs less than 22 kilograms and is easily portable with carrying handles or in a cart.

2. Introduction

The Dupont de Nemours Company has developed polyurethane "tote barricades" to protect personnel hand-carrying sensitive material from the effects of an accidental explosion. These barricades withstood the explosion of 2-g nitroglycerin only. Inspired by Dupont, this study was initiated at NPP to develop an explosive safety container able to withstand the explosion of higher loads of nitroglycerin than 2-g and to investigate the behavior of the container during an explosion. To be explosion-safe, the sample carrier was required to withstand a minimum load of 5-g explosive material. As an additional safety factor, the sample carrier (Figure 1) was to be fabri-

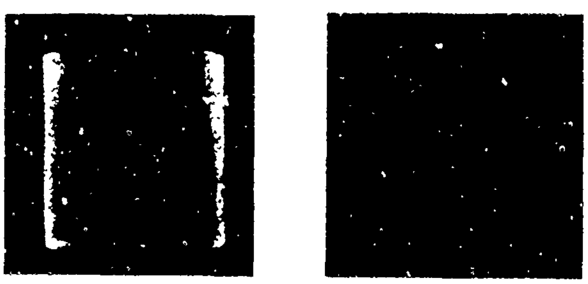


Figure 1
Polyurethane Safety Container of 8.1 cm Diameter with Inserted Polyethylene Vial of 1.25 cm Diameter.

Figure 2
Trace of a shock wave transmitted trough a polyurethane safety container by the explosion of 5—g nitroglycerin and an electric squib S—67 (DuPont) as a detonator. Writing speed: 0.6384/μsec.

Enclosure (1)

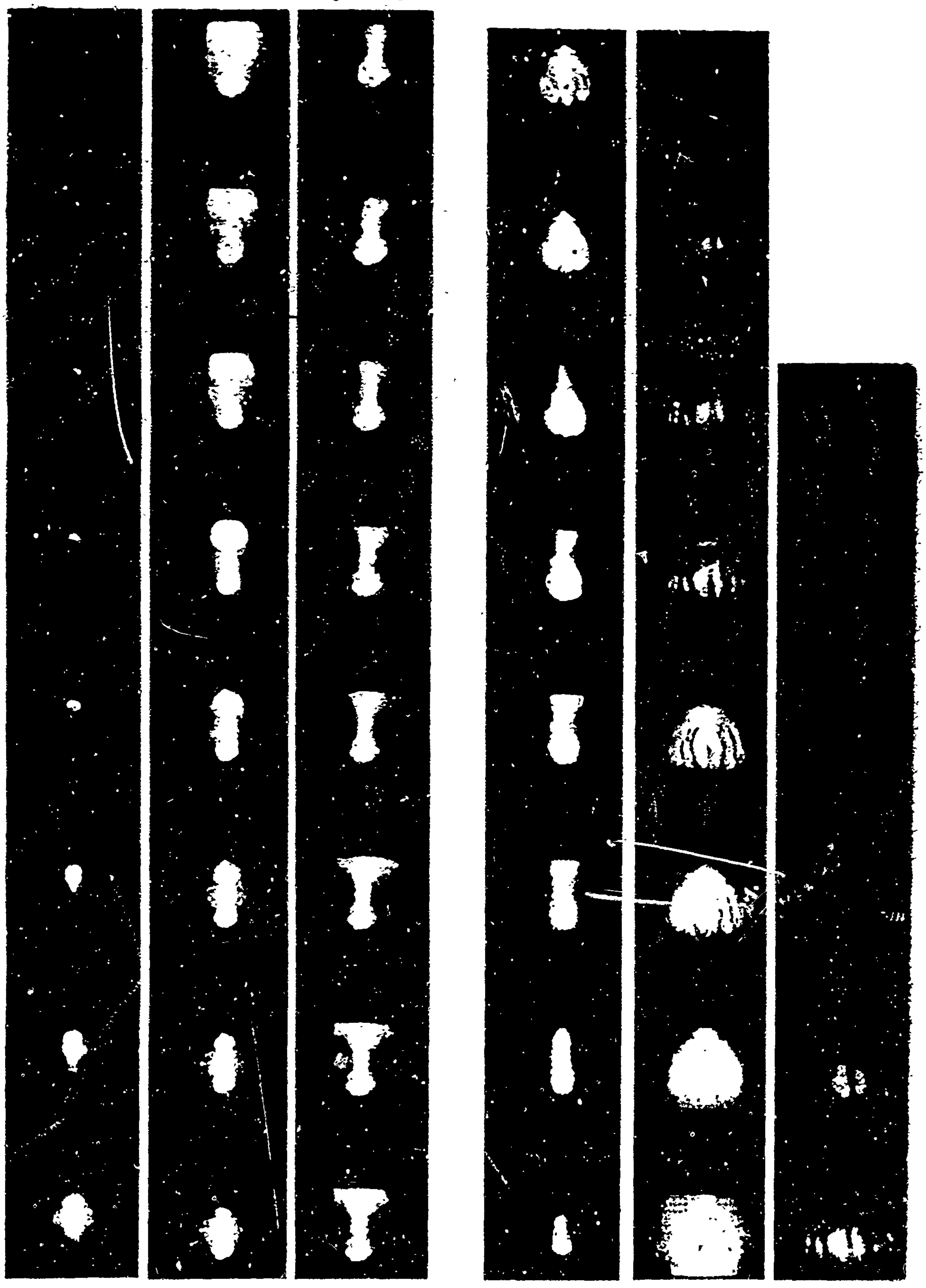


Figure 3

Figure 3a
Explosion of 2–g nitroglycerin in a polyurethane safety container. Framing rate: 240 000 PPS. Interframe Time: 4.2 μsec.

Figure 3b
Explosion of 5–g nitroglycerin in a polyurethane safety container. Framing rate: 62,500 PPS. Interframe time: 16 μs

ENCLOSURE (1)

cated from a material which would form harmless fragments upon break-up from a maximum load detonation. In other words, the material had to be one which would not form fragments or one which would form fragments which would be harmless to personnel.

Initially, an exploratory study with polyurethane containers (NPP formulation) was made, as polyurethane meets most of the prerequisites for a good safety container and is transparent so that the effects of explosion can be observed throughout the structure. Various other materials were investigated for possible use for containers.

Safety aspects of the containers with regard to the pressure on the user's hand during an explosion of a detonation-sensitive material will be reported later.

3. Experimental Methods

During this investigation a high speed framing camera and a high speed streak camera were used. The framing camera takes 25 pictures of events at rates up to 1.2×10^6 frames/second and the streak camera records detonation velocities with a writing speed up to 4.469 mm/µsec. A typical trace is shown in Figure 2. In order to trace the passage of a shock wave in an inert transparent material like polyurethane, an exploding wire in a capillary tube is used as back light [1, 2, 3].

The containers, 8.1 cm in diameter and 8.5 cm high, are filled with various loads of nitroglycerin During this investigation, nitroglycerin was employed as the standard explosive to determine maximum safe load for alle sample carriers studied. Since it was assumed that any accidental detonation would be initiated by a relatively small quantity of energy in form of shock, electrostatic energy, local heating effects etc., an S-67 Dupont squib or a 70 mg cyanuric triazide initiator jolted with 12.5 joules of current was used to explode the nitroglycerin. The resulting explosion phenomena of the nitroglycerin and the effects on the container are recorded with the cameras.

4. Results

4.1 Exploratory Investigation

Polyurethane explosive containers were fabricated with. 40 % Toluene Diisocyanate (80 20-2,4/2,6) and 60 % castor oil. The polyurethanemixture was poured into an appropriate mould and then a vial either of glass or plastic was immersed in the polyurethane which was cured for several hours at 80° C. Figure 1 shows an example of a safety container. The sample carriers were filled with 1—5-g nitroglycerin, and each one was set off while high speed framing sequence photographs of each shot were made. These photographs and the containers were then examined and the following observations were made. As expected, the "detonation" of nitroglycerin was of low order The low-order reaction will henceforth be termed an "explosion" rather than "detonation". During the explosion there were two destructive forces acting on the container. They were: The shock wave and the outward pressure exerted by the hot gasses from the nitroglycerin explosion. The container began to bulge within a few microseconds after the initiation of the explosion of the nitroglycerin, and fracture lines started to form soon thereafter. In Figure 3a and 3b are selected framing sequences for a 2-g and a 5-g load of nitroglycerin

The characteristic behavior of a polymer with increasing strain rates is analogous to its behavior with decreasing temperature conditions. The polyurethane is exposed to strain rates of 25×10^4 in/min therefore the percent elongation of polyurethane must be very small and the tensile strength relatively high.

Table I

Tensile Strength at 20 inches/minute Crosshead Rate

Test Temperature	Polyurethane Tensile Strength PSI¹)	Polyurethane Elongation %²)	Polyethylene Tensile Strength PSI¹)	Polyethylene Elongation %²)
25 C	203	126	2040	592
0 C	800	280	1840	580
—25 C	3622	236	—	—
—50 C	7133	12.3	—	—

1) Tensile Strength is based on original specimen area.
2) Elongation is calculated using an effecting length of 1.7 in. with ASTM D 412—51T DIE C.

Table I gives the tensile strengths and percent elongation for polyurethane and polyethylene for 20 in. min crosshead rate at various temperatures.

The container elongates along the circumference as the hot detonation gases expand. The inner circumference or wall of the container elongates at a much higher rate for a given radial expansion of the inner hole than for the zone farther from the center periphery. Therefore, the polyurethane starts to fracture from the inner wall when maximum elongation of the material is reached. In Figure 4 are sample containers after nitroglycerin has been exploded in them. The maximum nitroglycerin load limit for this polyurethane container is 3.5-g.

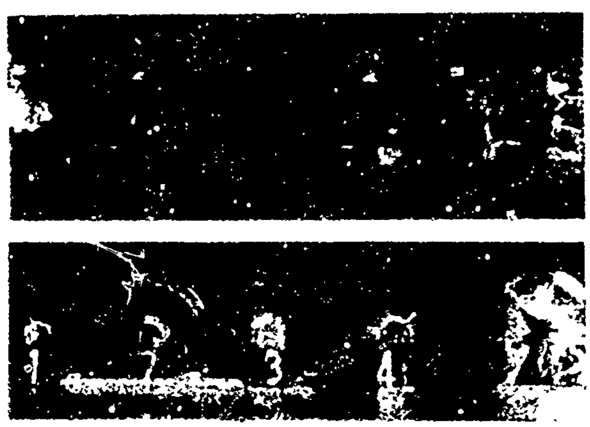


Figure 4
Polyurethane safety container after testing with varying loads of nitroglycerin

1: 1 —g nitroglycerin
2: 1.5—g nitroglycerin
3: 2 —g nitroglycerin
4: 4 —g nitroglycerin
5: 5 —g nitroglycerin

Approximately 50 mg cyanuric triazide and an exploding wire (5000 V, 3 µF) were used as detonators.

4.2 Strengthening the Polyurethane Container

After this preliminary study, the basic container was modified in several ways and tested with 5-g nitroglycerin. The total strength of the container can be increased by wrapping it with a strong cord or wire, or by encasing it with a strong metal tube. The dacron-wrapped container withstood a maximum load of 8-g of nitroglycerin. In Figure 5 are pictures of these containers and also one of an aluminiumencased polyurethane container after explosive testing. The reinforcements were removed in order to take pictures of the containers.

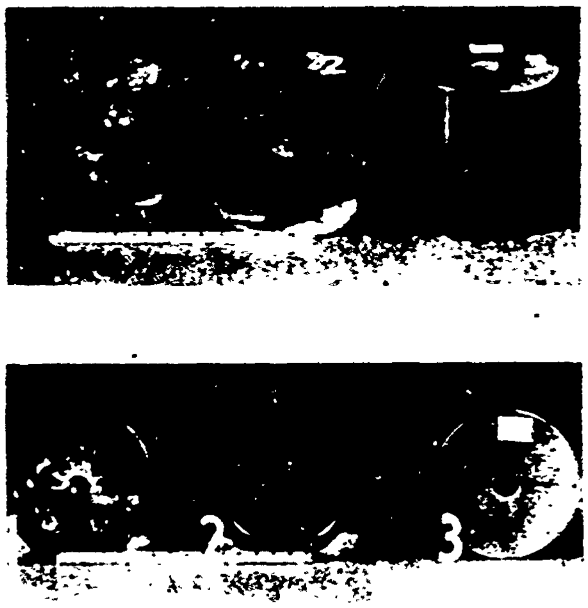
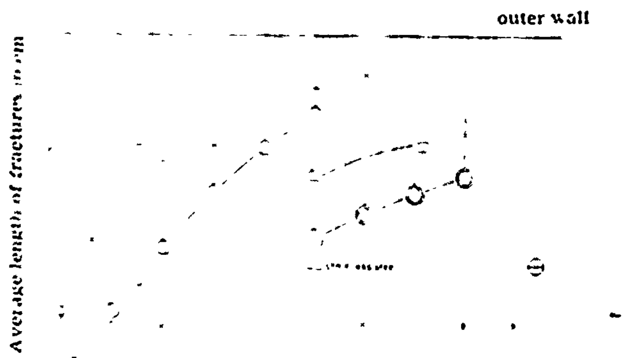


Figure 5
Polyurethane container with various reinforcements
1: 3 layers of dacron fishing cord 130 Pound test, after the explosion of 5—g nitroglycerin.
2: Aluminium outer walls (1.25 cm thickness), after the explosion of 5—g nitroglycerin.
3: Aluminium (7075—T—6) container after the explosion of 10—g nitroglycerin.



Polyurethane container without strengthening material
Polyurethane container strengthened with 3 layers of 120 Pd-test dacron line
Polyurethane container in Al-7075 T-6 casing
Polyurethane container strengthened with one layer nichromwire 101 Pd-test

Fig. 6
Fractures of Explosive Safety Container caused by Exploding Nitroglycerin

Figure 6 shows a plot of radial fracture line length versus nitroglycerin load. The basic unstrengthened container can safely withstand the explosion of only 3-g nitroglycerin in view of the fact that the fracture lines reach the outer wall of a 4-g nitroglycerin-tested container. Figure 6 also shows the increased load capacity for strenghened containers.

Various containers were fabricated with aluminum and stainless steel outer walls and tested with 5- and 10-g loads of nitroglycerin. Aluminum (7075 T-6) container with walls of 1.25 cm thickness was able to withstand the explosion of 9.5-g of nitroglycerin with no change in dimensions. Stainless steel containers with walls 1.8 mm thick were able to withstand the explosion of 5-g loads, but the steel casings were deformed to some extent.

To increase the tensile strength of the material, various amonts of glass wool, fiber glass fabric, and nylon fabric were added in a spiral pattern around the central tube. The tests showed that the increases in strength were not great enough to warrant further investigation along this line.

To interrupt the propagation of the shock wave and the fracture lines through the polyurethane material, the following containers were fabricated. Strips of polyurethane 8 cm wide and 0.15 cm thick were wound around a 1.25 cm vial until an 8 cm diameter was formed. Glass and polyethylene beakers and tubes were positioned concentrically around the central tube.

In all probability the poor bond between the polyurethane layers in the first case and between the polyethylene and polyurethane or glass and polyurethane in the second case weakened the structure of the containers, as they did not withstand the explosion of 5-g of nitroglycerin. However, there were indications that the polyethylene interfaces prevented propagation of fractures, more than glass did.

Air bubbles are good shock attenuators. (For example, in underwater explosions the measuring equipment is protected by surrounding it with a veil of air bubbles. [4] A large part of the shock energy is absorbed by the air bubbles.) Therefore foamed polyurethane was used to fabricate containers. The structure was weakened to such an extent by these modifications to the containers that no increase in the load capacity was observed.

4.3 Effect of Tube Material, Size, and Shape on Over-all Container Strength

Besides glass tubes, polyethylene of medium density and polypropylene of high density were used as vials for the containers. There was considerably less fracture formation in the polyethylene tube container when fired with nitroglycerin than in either the polypropylene or the glass.

The effect of the explosion velocity on the investigated safety container can be compared to the influence of the detonation velocity on the Trauzl-Block. Since high pressures in the detonation front correspond to high detonation velocities, the detonation velocity must be taken into account. These

...ous pressures are caused by the process of the reaction in the detonation zone. At high detonation velocities most of the chemical reaction occurs within the detonation zone. This generates very high pressures of very short duration. At low detonation velocity only a part of the chemical reaction takes place within the detonation zone, and there also is a chemical reaction behind the detonation front causing a lower pressure which acts over a longer period of time.

Nitroglycerin, as with many other explosives, has a low and a high order detonation velocity. Charge diameter and length, chemical characteristics, physical state and condition of the explosive and the amount of detonator determine the detonation velocities of the nitroglycerin. S[illegible] investigators [5, 6] have studied the parameters [illegible] the detonation of nitroglycerin and have established the high order (7800 m/sec) and the low order (2200 m/sec) detonation velocities. However, there seems to be little literature [7] available on explosive velocities for small detonators and small diameter charges.

The reaction process for explosions with small detonators seems to be an unsteady one. The initial explosion velocity is not sustained continuously. The nitroglycerin react[illegible] up as down the length of the tube as the [illegible] front passes. Since the detonation velocity [illegible] dependent upon the inner diameter of the [illegible] containing the charge, it was considered necessary in the case of the small (8 or 10 cm diameter) container to keep the tube diameter below the "critical diameter" for nitroglycerin initiated by small detonators. This "critical diameter" was measured at 12.5 mm. At this diameter, the explosion velocity [illegible] (185 m/sec and lower for smaller diameters) rises sharply and passes into a steady state detonation of high order with increasing diameter. To investigate this phenomenon measurements on the transition of deflagration to detonation of nitroglycerin have been initiated.

On the other hand, the ratio of the diameter of the tube to the length of the charge should be kept as high as possible so that a steady-plane detonation wave cannot build up as easily as it would if the charge length were high in comparison to its diameter. The possibility was considered that changing the shape of the vial might enable the container to withstand the explosion of higher loads of nitroglycerin, either by inclosing the blast or, by its shape, directing most of the blast effect upwards. For a 5-g load of nitroglycerin, no observable advantage in any specific shape was found. Since the cylindrical tube was the easiest to fabricate, all further containers had tubes of this shape.

4.4 Effect of Container Material and Size on Nitroglycerin Load Capacity

Table II lists the various container materials which were tried. Containers 10 cm in diameter were fabricated with 12.5 mm I. D. holes and were fired with 5-g of nitroglycerin. The aluminum and the medium-density polyethylene were the only containers that withstood the explosions. The aluminum container also withstood the explosion 10-g of nitroglycerin with very little change in either the inner or outer diameter (see Figure 5).

The polyethylene container withstood the explosion of 10-g of nitroglycerin with very little outside deformation. However, there was some change in both inner and outer diameter with a 15-g load of nitroglycerin (see Figure 7). The container sustain-

Table II

Materials and Dimensions of Tested Containers

Material	Diameter of Container	Diameter of Hole	Length of Hole	Load of NG
Polyurethane	8.1 cm	[illegible]	[illegible]	[illegible]
Polyurethane strengthened with Dacron Line	8.1 cm	1.25 cm	4.5 cm	( ) 5 g
Polyurethane with Steel incasing	8.1 cm	1.25 cm	4.0 cm	( ) [illegible]
Polyurethane with Aluminum incasing	7.5 cm	1.25 cm	5 cm	( ) 10 g
Polyethylene Medium Density	10 cm	1.25 cm	6.5 cm	( ) 5 g
	10 cm	1.25 cm	7.0 cm	( ) 10 g
	10 cm	1.35 cm	7.0 cm	( ) 15 g
7075-T-6 Aluminum	8.7 cm	1.25 cm	6.0 cm	( ) 10 g
Nylon	10.1 cm	1.25 cm	5.0 cm	( ) 5 g
Lucite	10.1 cm	1.25 cm	[illegible]	( ) 5 g
Polystyrene (Crosslinked)	10.1 cm	1.25 cm	5.0 cm	(—) 5 g
Polyvinyl Chloride	10.1 cm	1.25 cm	5.0 cm	( ) 5 g
Teflon	10.1 cm	1.25 cm	6 cm	(—) 10 g
Polypropylene	10.1 cm	1.25 cm	5.0 cm	(—) 5 g
Polyethylene	31.2 cm	2.3 cm	17 cm	( ) 100 g
	31.2 cm	3.06 cm	22.1 cm	( ) 250 g
	31.2 cm	5.08 cm	16.5 cm	( ) 500 g

( ) Did withstand the explosion of the indicated amount of nitroglycerin.
(—) Did not withstand.

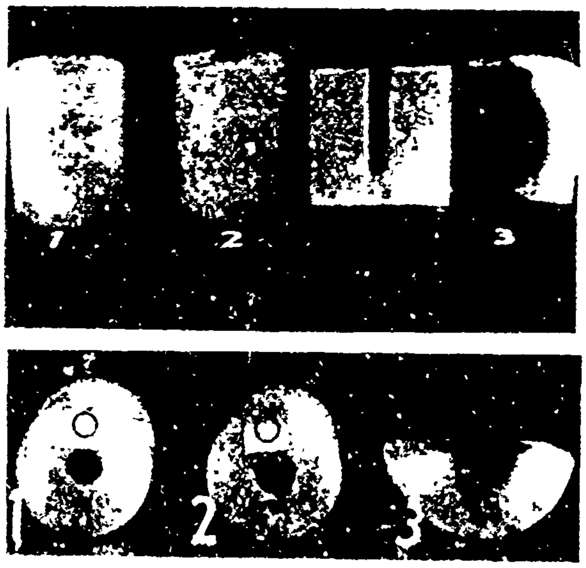


Figure 7
Polyethylene container tested with varying loads of nitroglycerin
1: 5-g nitroglycerin + squib A67
2: 10-g nitroglycerin + squib A67
3: 15-g nitroglycerin + squib A67
The circles on containers 1 and 2 show the original sizes of the hole before testing. For container 3, the original size is drawn on the paper beside the tested container. To see better the bulging of the hole, this container was bisected.

ed the detonation very well, and no fracture lines could be seen. It is evident that the expansion of the container hole during the explosion increases downwards. This is because the pressure acts for a longer period of time on the end of the charge than on the top of the container, where the explosion gases can escape faster. A. Haid and H. Koenen [9] found that there was considerably less expansion of the container hole in using high density explosive in the Trauzl-Block than low density explosive. In testing the containers, therefore, it should be taken into consideration that the bulging of the container would be influenced by the density of the explosive as well as the amount.

Polyethylene containers 32 cm in diameter were tested at 100 and 250-g of nitroglycerin with very little outside deformation (some inner deformation). At 500-g nitroglycerin load, the container deformed to some extent (see Figure 8). The container sustained the deformation well.

Figure 8
Polyethylene safety containers after the explosion of 100—g, 250—g, and 500—g of nitroglycerin.
The circles on top of each container indicate the original sizes of the holes (compare also Table II).

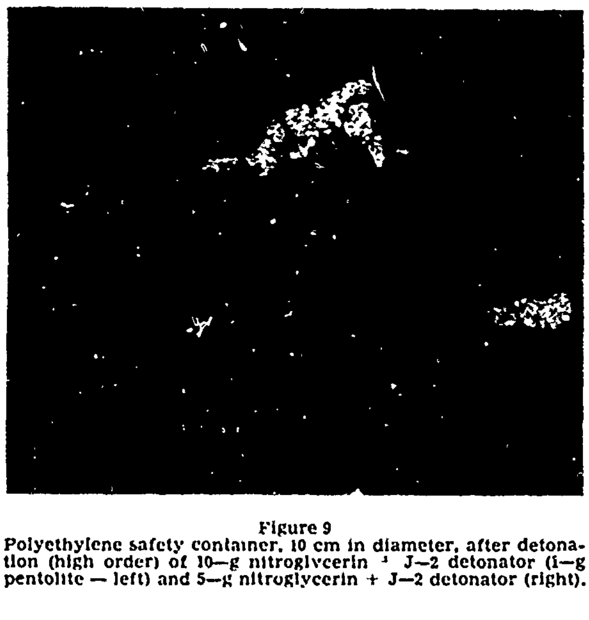


Figure 9
Polyethylene safety container, 10 cm in diameter, after detonation (high order) of 10—g nitroglycerin + J—2 detonator (1—g pentolite — left) and 5—g nitroglycerin + J—2 detonator (right).

Polyethylene is a good material for explosive safety containers. It has the mechanical properties which suit the containment of an explosion. It has a high percent of elongation (up to 600 %) before breaking and a relatively high tensile strength. It has very good cold flow properties and deforms rather than fracture even at high strain rates.

Polyethylene has an arrangement of threadlike molecular carbon chains which is intermediate between those of the two conventional types: one the completely ordered or crystalline arrangement, and the other a purely random or amorphous one. With these two arrangements, the polymer is both tough (due to its crystalline qualities) and deformable (due to its amorphous arrangement). Ordinary polyethylene has a high degree of crystallinity (around 60—70 %) as it has been estimated from x-ray studies [8].

During most of this study, the nitroglycerin was initiated to a "low order explosion" by a DuPont S-67 squib, jolted to detonation by passing 12.5 joules of electricity through it. These explosions would thus correspond to accidental explosions, as mentioned above, since any accidental explosion would be activated by a relatively small quantity of energy.

It is of interest, however, to determine how the container withstood a high order detonation. Figure 9 shows the 10 cm diameter polyethylene explosive sample container after detonating 5 and 10-g of nitroglycerin to high order by a Hercules J-2 blasting cap (12.5 joules). The J-2 blasting cap has a 1-g pentolite load. The container withstood, essentially the detonation of a 6-g load (5-g NG + 1-g explosive in blasting cap), with some deformation. The 10-g nitroglycerin loaded container (+ J-2 blasting cap) ruptured along the weaker side.

5. Conclusions and Future Work:

It was found that medium density polyethylene is an ideal material to use to fabricate explosive safety containers. A container 10 cm in diameter can easily withstand the explosion of 15-g nitroglycerin and a 32 cm diameter container, 500-g of nitroglycerin, if small detonators are used*). The handcarried 10 cm diameter container deforms slightly with the explosion of 15-g of nitroglycerin. The "critical" diameter for low order nitroglycerin explosions initiated by S-67 DuPont squibs was found to be 12.5 mm.

Some pressure measurements on the container walls during the explosion will be made in order to obtain some information on the pressure shock acting on the user's hand.

To protect personnel synthesizing hazardous material the equipment needed for synthesis will be coated with polyethylene.

LITERATURE

[1] H. Bartels and Eiselt, Optik 6 56—58 (1950).
[2] T. P. Liddiard, U. S. Naval Ord. Lab., Memo 10840 (1950).
[3] W. M. Conn. J. Opt. Soc. Am. 41 445—449 (1951).
[4] U. S. A. Patent 2699117 (1954); Bachus, Der Bauingenieur 30 1267 (1955).
[5] J. Taylor. "Detonation in Condensed Explosives", Oxford 1952.
[6] J. B. Chariton, S. B. Ratner, Compt. rend Acad. Sci N. R. SS. 41 293 (1943).
[7] E. Haeuseler, Explosivstoffe 516, 64 (1953).
[8] G. F. Kinney "Engineering Properties and Applications of Plastics, 1957, New York, J. Wiley and Sons, Inc
[9] A. Haid, H. Koenen Zeitschr. f d ges Sprengstoffwesen 28 12 (1933) 29 4 (1934).
A. Schmidt, Explosivstoffe 7 11 (1959)

*) DuPont S—67 squib

ENCLOSURE